Explosion Puffing of Mushrooms

John F. Sullivan and Mary Jo Egoville

U.S. Department of Agriculture, Agricultural Research Service, Eastern Regional Research Center, Philadelphia, Pennsylvania 19118 (U.S.A.)

(Received January 14, 1986; Accepted February 17, 1986)

Mushrooms were explosion puffed successfully at 1.65 × 10^5 Pa, 121°C and at a moisture of 19%. The product was light in colour with bacteria counts of less than 10^4 cfu/g. The dried mushrooms had a very strong, pleasant mushroom flavour, rehydrated in boiling water in 5 minutes and were slightly chewy. The rehydrated mushrooms retained enhanced mushroom flavour.

Introduction

Mushrooms, a gourmets' delight, supply B vitamins and amino acids to the diet (1). They are low in calorie count with a delicate, appealing flavour. For this reason, they can be used in combination with other foods or alone as a snack.

Fresh mushrooms are extremely perishable; loss of colour is almost immediate, and they should be eatern within a week of picking. Processing (canning) has been used as a means of extending their availability, but large amounts of solids, B vitamins and amino acids are lost in blanching (2, 3). Alternative processing methods have been explored. Freeze drying gives a low-density, high-quality, but expensive product (4).

Although of low cost, hot-air dehydration has been an unacceptable method of preservation as the rehydrated product is tough, chewy and has an 'off' flavour. In 1970, scientists at the Agricultural Research Service's Eastern Regional Research Center developed a method which overcame these difficulties (5). However, this method required a prolonged dehydration time even at low production rates.

Explosion puffing is a feasible operational step (6) during hot-air dehydration and was used as a means of reducing dehydration time and increasing drying capacity. Explosion puffing requires partly dried food pieces (*ca.* 25% wet basis) to be put under pressure with superheated steam. After approximately 1 min the pressure is instantly released from a discharge chamber (6). This causes some of the moisture to vaporise and creates a porous structure in the food pieces which require further drying for adequate storage. This paper reports the feasibility of using the explosion-puffing step in conjunction with hot-air dehydration to reduce dehydration and re-hydration time, retain nutrients and yield a higher quality of dried mushrooms.

Materials and Methods

Cultivated mushrooms which were supplied by the Mushroom Cooperative Company* of Kennett Square, PA, were used in this study. Mushrooms came from lots stored at 3°C. Two sizes were used in the experiments; #3 (whole mushroom) and #5 (11-mm random slices). On the day of the experiment, the mushrooms were removed from the storage room and placed on vibrating rods to remove loose soil. The mushrooms were dry vacuum-cleaned and then flumed through a rod-reel washer and sized. The #5 samples used in the experiments were randomly sliced (11 mm maximum) in an Urschel cutter (5). The mushrooms were packed into 20-lb freezer cartons and transported by car from Kennett Square to the Center (about 1 h).

The whole mushrooms were split into three fractions: whole mushrooms, buttons ('tops' or 'caps') and stems. These fractions were sulphited as follows. Each fraction was placed into an enclosed stainless-steel wire-mesh basket and put into a 210-l stainless-steel drum containing 0.5% sodium bisulphite solution. The sulphite solution was forced through the mushrooms by a 375-watt Eastern pump which circulated the sulphite solution from the bottom to the top of the drum for 3 min. The 11-mm slices (a later experiment) were placed in a 1.0% sodium bisulphite solution and the sulphite solution circulated for 5 min.

After sulphiting, the baskets of mushrooms were removed from the drum and drained. The drained pieces (whole, stems, buttons and slices) were put into drying trays, weighed and then dried in a through-circulation hot-air tray dryer (National Drying Machinery Co.). The mushrooms were dried to a predetermined end weight, which theoretically gave 25% moisture. The air velocity was 1 m/s and the drying temperature 77°C.

To find feasible operating conditions for mushrooms in continuous explosion puffing system (CEPS) (6), small amounts of mushrooms (60 g each) were fed batchwise to the CEPS. Pressure varied from 1.2 × 10^5 to 3.4 × 10^5 Pa, and the internal temperature varied from 121 to 232°C. The bulk of the mushrooms were then fed to the CEPS at the best conditions observed. These conditions were determined by taking each small batch and examining it after explosion puffing (a) for colour change (darkening from nonenzymatic browning) and (b) for porosity change (an expansion of the mushrooms toward their original fresh-cut size). Then, from these observations, an increase or a decrease in either pressure or internal temperature or both was made to give a product with less colour change and as much porosity as possible. After explosion puffing, the mushrooms were returned to the tray dryer and dried to 5% moisture. The dryer was set at 55°C (dry-bulb air temperature) and the air velocity at 1 m/s.

Product evaluation was done by examining colour difference, vitamin retention, sulphur dioxide levels and bacteria count. All analytical determinations were done in triplicate.

* References to a brand or firm name does not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature not mentioned

Colour

Colour was determined on dried mushroom powder. This was obtained by grinding dried mushrooms in a Waring Blendor, then passing the ground material through a Wiley mill 20-mesh screen. Colour determinations (7) were done using a Gardner Model XL-23 colour difference meter. The meter was standardised with a Gardner ceramic standard CLY0032 (R_d = 60.8, $a = -1.8$, $b = +22.7$). Colour values for each sample were obtained as Hunter a, b and R_d units (7).

Vitamins

A 3.0-g dry, ground sample of mushrooms was analysed for determination of each of the vitamins: thiamin, riboflavin and niacin. A Technicon Autoanalyser was used. The procedures are described in Technicon's Industrial Manual (8) as Methods 479-77A (thiamin), 140-71A (riboflavin) and 156-71A (niacin).

Sulphur dioxide

The sulphur dioxide content was determined by using a distillation procedue (9). The apparatus used was based on the Monier Williams principle of distillation under reflux in a stream of nitrogen carrier gas.

For each sample, 4.0 g of dried mushroom powder (through 20 mesh) were introduced into a two-neck, 1000-ml round-bottom flask containing 300 ml deionised water. Five millilitres of 25% phosphoric acid were added, and the nitrogen gas flow adjusted. The sulphur dioxide was distilled into a collection vessel containing 20.0 ml of 0.01 N iodine solution. The round-bottom flask was heated for 30 min (low flame). The amount of unreacted iodine was titrated with 0.01 N sodium thiosulphate.

Microbial count

A standard microbial plate count method was used. Ten grams of mushrooms and 90.0 g of sterile peptone water (1 g/l peptone) were placed aseptically into a sterile Waring Blendor and mixed at high speed for 5 min. The mixture was serially diluted from 10^{-2} to 10^{-7} using sterile dilution blanks (99.0 ml peptone water). Duplicate plates were made at each dilution. The plating medium used was Difco standard methods plate count agar. Plates were incubated aerobically at 27°C for 48 h.

Results and Discussion

Low-temperature dehydration (5), as discused in the Introduction, is slow, but the product has good colour and low sulphur dioxide content. For convenience, high-temperature air dehydration was used for these experiments. High concentrations of sodium bisulphite solutions were needed to prevent colour change. When sulphite was not used, the dried mushrooms were black; R_d, the reflectance value, was almost 1. **Table 1** shows the colour difference values and the sulphite concentrations. The colour difference for run 1 was determined from a blended mixture of dried caps, stems and whole mushrooms. These mushrooms were treated with 0.5% sodium bisulphite solution. Run 1 (dried, explosion-puffed product) had poor colour and low sulphite retention. A great improvement in colour was observed in the product from run 2. This was entirely due to the increase in sulphite concentration and time of dip for the fresh mushrooms. Unfortunately, improved colour control was associated with higher sulphite retention (820 p.p.m.).

Table 1 Colour difference and sulphur dioxide content of dried mushrooms

Run	Colour			Sulphur dioxide (p.p.m.)
	R_d	a	b	
1	23.0	+5.1	+16.3	64.3
2	33.1	+3.5	+18.7	820

Optimal operating conditions for explosion puffing of mushrooms in the CEPS were determined as pressure, 1.65×10^5 Pa, temperature, 121°C, and the mushrooms at a moisture of 19% (wet basis). After explosion puffing, the mushrooms of runs 1 and 2 were dried to *ca.* 5% moisture in a tray dryer at 54°C. The products from both runs 1 and 2 had a greatly reduced bacterial content. This resulted from their exposure to high-temperature superheated steam (121°C) for 40 sec in the CEPS. The bacteria count was reduced without blanching or use of chlorine water treatment. The bacteria count is shown in **Table 2**. **Table 3** shows the B vitamins, thiamin, riboflavin and niacin, on a moisture-free basis. Unfortunately, the raw mushrooms were not analysed; therefore, the only comparison was with values from the *USDA Handbook No. 8* (10). Riboflavin and niacin were not lost during hot-air dehydration and explosion puffing. Thiamin was lost because of its reaction with sulphite (11). This is observed in **Table 3**, as pieces from run 1 were treated with 0.5% sodium bisulphite solution and slices from run 2 with 1.0%.

Table 2 Bacteria count of mushrooms

Run	Fresh	Explosion puffed and dried
1	1.3×10^9 cfu/g	7.5×10^3 cfu/g
2	1.1×10^8 cfu/g	1.0×10^3 cfu/g

Table 3 Vitamin B content* of mushrooms

Run	Thiamin (μg/g)	Riboflavin (μg/g)	Niacin (μg/g)
1	236	2560	37500
2	79	3820	37600
Handbook No. 8 (10)	1000	4600	42000

* Moisture-free basis

Dried samples from run 2 rehydrated in boiling water in 5 min. The colour was light grey. They maintained enhanced mushroom flavour but were slightly chewy when compared to fresh cooked mushrooms.

Conclusions

Mushrooms can be hot-air dehydrated and explosion puffed. The dried mushrooms should make an excellent snack food and can supply a significant amount of the ROA (recommended dietary allowance) of riboflavin and niacin, as well as some thiamin. The explosion-puffing step reduced the bacteria count to a sanitary level. High concentrations of sodium bisulphite solutions allow fresh mushrooms to be dried at high air temperatures without materially affecting colour. The rehydrated dried mushrooms can be used as a food condiment or as an ingredient in a soup.

References

1 Brunel, H.J., Esselen, W.B., Jr. and Griffiths, F.P. *Food Industries*, **15** (11), 74 (1943)

2 Mcardle, F.J. and Curwen, D. *Mushroom Science* **5**, 547 (1982)

3 Kozempel, M.F., Sullivan, J.F., Dellamonica, E.S., Egoville, M.J., Talley, E.A., Jones, W.J. and Craig J.C., Jr. *Journal of Food Science*, **46**, 1519 (1982)

4 Van Arsdel, W.B., Copley, M.J. and Morgan, A.I., Jr (Eds). *Food Dehydration*. Westport, CT: AVI Publishing Company, Inc. (1973)

5 KOMANSKY, M., TALLEY, F.B. AND ESKEW, R.K. *Food Technology*, **24** (9), 80 (1970)
6 SULLIVAN, J.F. AND CRAIG, J.C., JR. *Food Technology*, **38** (2), 52 (1984)
7 HUNTER, R.S. *National Bureau of Standards (US) Circular* C429. Washington, DC: U.S. Government Printing Office (1952)
8 TECHNICON. *Technicon Autoanalyzer II, Industrial Method Nos. 479–77A, 140–71A and 156–71A*. Terrytown, New York: Technicon (1977)
9 BURROUGHS, L.F. AND SPARKS, A.H. *The Analyst*, **88**, 304 (1963)
10 ARS–USDA. *USDA Handbook No. 8*. Washington, DC: ARS-USDA/U.S. Government Printing Office (1963)
11 SULLIVAN, J.F., KOZEMPEL, M.F., EGOVILLE, M.J. AND TALLEY, E.A.

A Study of Some Factors Influencing the Tenderness of Turkey Breast Meat

T. C. Grey,* N. M. Griffiths, J. M. Jones† and D. Robinson*

AFRC Food Research Institute, Norwich, Colney Lane, Norwich NR4 7UA (United Kingdom)
(*Received January 21, 1986; Accepted March 18, 1986*)

The tenderness of cooked breast meat was influenced by the type of diet fed to five strains of turkeys. Generally a high-energy, low-protein diet produced a tender meat. The chemical composition of the meat did not influence the tenderness. The variation in tenderness between birds was apparently related to variation in muscle structure.

Introduction

Both turkey processors and sectors of the British retail trade believe that of the various factors determining the quality of turkey meat, tenderness is of extreme importance to the consumer. Consequently, emphasis is placed on achieving acceptable and uniform tenderness. However, variations in tenderness of the meat, particularly from the breast, are reported from time to time.

Factors likely to influence the tenderness of poultry meat may be divided into three broad areas, namely, the birds themselves, preslaughter handling and, finally, processing conditions. Of these, the possible influence of bird strain and husbandry seems to have been neglected in recent years despite evidence that both might be important (1,2). Since both the genetic make-up of the turkey and the husbandry regimes under which birds are reared have changed considerably in the last 20–30 years, we undertook an investigation into the influence of bird strain and diet on the tenderness of breast meat from birds currently available to the British turkey industry.

Materials and Methods

Management and processing

Three experiments were carried out in collaboration with Mr C. Nixey of British United Turkeys, using altogether five strains (A–E) of male turkeys. All turkeys were grown in pens at a maximum stocking density of 34 kg/m^2. The age, sex and numbers of birds used in each experiment were as detailed below.

Experiment 1. 16-week males, three strains (A, B and C) on diets 1 and 2 (see below), 20 birds/strain, total of 60 birds.

Experiment 2. 16-week males, two strains (C and D) on diets 1 and 3, 20 birds/strain, total of 40 birds.

Experiment 3. 20-week males, three strains (C, D and E) on diets 1 and 3, 32 birds/strain, total of 96 birds.

In each experiment half the birds used had been fed on a low-energy UK-type ration, i.e. one containing wheat and barley (diet 1). In experiment 1 comparison was made with birds fed for weeks 12–16 on a commercial diet containing 200 g/kg protein (BOCM 631, diet 2).

In experiments 2 and 3, diet 1 was compared with high-energy American-type rations containing maize up to a level of 800 g/kg (diet 3). The levels of crude protein and the ratios of metabolisable energy to crude protein of the low- and high-energy diets are given in **Table 1.**

Table 1 Energy and protein relationships during growing periods for experiments 2 and 3

Diet 1			Diet 3		
Weeks	Crude protein (g/kg)	ME:CP*	Weeks	Crude protein (g/kg)	ME:CP*
0–4	283	41.0	0–4	245	48.5
4–8	271	42.8	4–8	220	56.0
8–12	217	53.4	8–12	195	66.1
			12–16	161	82.4
12–20	189	62.8			
			16–20	144	93.8

* ME, metabolisable energy (MJ/kg); CP, crude protein (g/kg)

After commercial processing, the eviscerated carcasses (weighing from 6.0 to 13.5 kg according to the experiment in progress) were bagged and transported to the Food Research Institute (FRI) either in the chilled state and held at −2°C (experiments 1 and 2), or (experiment 3) frozen at the processing plant and kept at −30°C until sampled at FRI.

Assessment of texture

Sample preparation and panel evaluation were carried out as described by Griffiths *et al.* (3).

Texture was evaluated by 14 experienced assessors who rated the samples on the following scale: 1, extremely tender; 2, very tender; 3, moderately tender; 4, slightly tender; 5, slightly tough; 6, moderately tough; 7, very tough; 8, extremely tough.

Chemical analysis

Protein, moisture and fat were determined as described by Grey *et al.* (4). Collagen was estimated according to ISO method 3496 (5).

Histological examination of muscle

Samples of cooked breast muscle (approximately 1 × 1 × 2 cm) were taken from a position adjacent to the area of muscle used for taste panel assessment and fixed in a solution containing formalin 40 g/l and calcium chloride 10 g/l. They were stored in glass bottles secured with a screw-cap.

* Present address: AFRC Food Research Institute, Bristol, Langford, Bristol BS18 7DY (England)

† Present address: 18 Sywell Close, Old Catton, Norwich NR6 7EW (England)